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Fish and Wildlife Service, Albert M. Day, Director

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PACIFIC OCEANIC FISHERY
INVESTIGATIONS

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THE PACIFIC SARDINE FISHERY[1/]

The Pacific sardine or pilchard resource is unique. It supports the largest fishery in the western hemisphere--nearly 25 percent of all fish caught in the United States are sardines; it is the cheapest source of protein food for human consumption; it is the most important source of fish meal and oil which are vital in the nutrition of poultry and other livestock. It yields the largest volume of canned fish produced in the United States (exclusive of Alaska); and is an important source of vitamins A, D, B_1 and G(B_2).

The Pacific sardine (known scientifically as Sardinops caerulea) is a pelagic fish, traveling in the upper layers of the ocean in schools or shoals of varying size from a few tons to hundreds of tons of fish. The characteristics of the sea water rather than the sea bottom direct their movements and because these characteristics are constantly changing, the sardines constantly move. They do this vertically as well as horizontally, so that at times schools travel at the surface, at other times well below, and the luck of fishermen fares accordingly.

Sardines spawn in the open sea, usually 50 to 200 miles offshore, with some spawning taking place at least as far seaward as 300 miles. The north to south range of spawning is not well known, but there is some evidence that it may extend from British Columbia to the southern tip of Lower California, at least in some years. Off southern California, where spawning has been investigated, the season extends from January through June, reaching its height in late March or early April. The eggs are fertilized in the open water, drift passively in the upper ten fathoms, and hatch in about three days. Great fecundity offsets high infant mortality, each female laying about 35,000 eggs in a batch, and perhaps as many as three batches in one season. The young fish drift with currents for several months. They feed then, as they do throughout life, on minute organisms, plant and animal, which live suspended in the sea water and are collectively called plankton.

Though initially of tremendous numbers, the brood is rapidly thinned out in the struggle for existence. The conditions affecting this struggle for existence, such as food supply and submarine climate, fluctuate constantly, and cause great fluctuations in the infant survival rate. These variations are later reflected in the commercial catch when the young grow to adulthood.

1/ Prepared by the staff of the South Pacific Section of the Division of Fishery Biology.

As the juvenile sardines grow, their swimming efforts become stronger and they congregate in schools like those of their parents. When from 3 to 5 inches long, they migrate toward shore, where they remain to feed for a time. While there they are caught in large numbers by fishermen for tuna bait and to supply bait to sport fishermen. The main known nursery grounds are off southern California and Lower California, Mexico; areas of fluctuating, though generally of lesser, importance extend northward to British Columbia.

When the sardines have grown to about 7 inches in length, they begin to leave their inshore nursery grounds and take up the pelagic offshore life of adults. Then they make their first appearance in the regular commercial fishery. The fish do not all enter the commercial catch at the same length; only a small percentage of the sardines as short as 7 inches are caught and none that small are wanted. By the time the fish are 10 inches long, however, practically 100 percent of them become available to the fishery and are aggressively sought. Generally, the youngest fish are found first most abundantly in southern California (the fishing regions nearest the spawning areas), and later in the more northerly (remote) grounds, though there are some exceptions. Sardines become sexually mature at about 7 to 10 inches in length, 1/10 to 1/4 of a pound in weight, and at 1 to 3 years of age. According to scale studies, the natural full life span is something over 10 years; a few specimens of 13 years have been collected.

Tagging experiments by the research agencies of California, Oregon, Washington, and Canada have proved conclusively that some sardines migrate from California to British Columbia, and vice versa. The exact extent and nature of these migrations, however, are difficult to study and are still imperfectly understood. Present available evidence indicates a northward feeding movement in summer and a southward movement toward spawning grounds in fall and winter. The fish appear to migrate increasing distances as they grow larger.

Owing to fluctuations in infant mortality, the size of broods of young varies greatly from year to year. These variations are probably the consequence of changing food supply, among other things, which is accompanied by fluctuating saltiness of the sea water and perhaps by other things about which little is yet known. Fishermen's luck depends not only on these fluctuations, but also on the behavior of the fish moving in response to the changes of currents and other conditions in the sea, making them sometimes hard to find and catch and sometimes easy. The catch of sardines is influenced not only by these natural conditions, but also by the amount of fishing, i. e., by the amount and type of gear used and the length of time it is used.

The ultimate effects of fishing on this as on any stock can be--(1) Reduction in total number of fish in the stock, producing a smaller yield for a given amount of fishing effort; (2) reduction in the average size of the fish in the stock, thus necessitating catching more fish to sustain the tonnage; (3) reduction of the stock of fish to a point where the annual catch which may be sustained is reduced; (4) decimation of the spawning stock to below a safe level, finally leading to successively smaller annual catches. The first effect starts in some degree, even though slight, as soon as any fishing effort is applied. The second effect has evidenced itself. Sardines have been averaging smaller and younger in recent years than formerly. For detecting the third and fourth effects, the information at hand is insufficient. Because of the great natural changes in the size of the population, a great deal of marine research will be required before enough is known along this line. Research directed toward measuring the effect of the oceanic environment on the species so that it may be discounted and thus allow the effect of the fishery on the stock to stand clear is a prime necessity for the future welfare of the industry.

Under present fishing intensities probably as much as half the adult sardines are caught annually, on the average. The majority of sardines are less than 4 years old, few last longer than 7 years. Such a young stock has both advantages and disadvantages. Among the former are a rapid growth rate and a high rate of replacement. One important disadvantage at present seems to be the relatively small size of the fish. When exceptionally small fish are brought in, as sometimes happens under current conditions, the fish plants experience difficulty in processing the catch. If small fish become extremely common, the industry would have the problem of adjusting itself to a new and perhaps difficult condition. Another disadvantage, from a standpoint of stability in the industry, is that when the stock is made up of a small number of year classes, the fluctuations in the size of the stock due to variations in year-class strengths are more violent than if "buffered" by the averaging effect of a large number of year classes.

The sardine resource can be soundly managed only after determining what continuing yield in total tonnage, in catch-per-unit-of-effort and in sizes of fish can be expected from various fishing intensities. To accomplish this, it is necessary to separate the effects imposed on the size of the stock by man's fishing from those imposed by nature's complexly interrelated systems of influences. This involves analyses of statistical records on the fishery as well as on all phases of the sardine's life and its environment.

The several Pacific Coast States and the Fishery Research Board of Canada have long collected fishery statistics. In addition, with the help of the United States Fish and Wildlife Service, they maintain a sampling system for keeping record of sizes, ages, sex, and weights of the fish composing the catch; and continuously analyze these data.

Most seriously lacking are adequate observations at sea of oceanic conditions as they affect reproduction, behavior, and catch. The conservation agencies of California, Oregon, and Canada have studied migration by tagging. The Fish and Wildlife Service has made serveral partial surveys of spawning and ocean conditions affecting the survival of spawn and fry in a very limited section of the tremendous spawning grounds; it has also made some preliminary studies of the weather's effects on fishing luck. These studies merely furnish background demonstrating the necessity for much more intensive and extensive observations on the living sardine population and on the marine world which it inhabits.

Legislative control of the sardine resource is in the hands of the several Coast States and the Dominion of Canada. In Canada, Washington, and Oregon, sardine fishing is unrestricted; and general restrictions on the use of fishing gear in certain areas do not materially affect the sardine fishery. In California, general restrictions on the use of gear, especially in certain areas, have little effect on the exploitation of the resource. There are closed seasons, not on fishing, but on the use of sardines for canning and reduction, which tend to restrict the large-scale operations in the industry to the fall and winter months when the fish are of best quality and the catch is most reliable. This restriction promotes efficiency in operation of processing plants and boats. It has little effect on sustaining the yield or protecting the resource; it simply allows more fish to be caught for a given amount of effort and more processed product to be obtained from the tonnage caught, than if the fishery were spread over the entire year.

More specifically directed toward sustaining the yield (through avoidance of over-utilization) is California's regulation of the use of sardines for reduction to oil and meal. Sardines may be used for reduction only under these conditions: A certain percentage of the sardines received for canning may be reduced; and further, the Fish and Game Commission may grant permits to reduce fish if such use does not tend to deplete the species and if it would promote the economic utilization of the fish resource.

As long as California catches by far the largest share of the total Pacific Coast fishery and only a small part of this catch is absorbed by canning, the authority to regulate the amount used for reduction effectively limits the total catch to the total amount which, in the judgment of the California Fish and Game Commission, the resource can support. For the season of 1946-47 and for several previous seasons the quantity authorized to be used for reduction under permit has been 395,000 tons and the quantity that has been used for canning has averaged about 275,000 tons or a total authorized usage of nearly 670,000 tons. The catch has averaged about 500,000 tons. The difference represents the amount by which the tonnage used for reduction actually fell short of the amount authorized under permit by reason of insufficient catches at one or several of the ports.

Present status of the sardine resource. Utilization of the sardine resource on a large scale began with the war of 1914-18 as a canned-fish industry. Adoption of the continuous screw press in the 1920's enabled utilization, first, of cannery waste for the manufacture of fish meal and oil, subsequently, of whole fish for this purpose; and the reduction process has proved to be often more profitable than the canning process. There is now practically no limit to the amount of finished product that can be absorbed. The field for marketing sardine products is as wide as the markets for protein foods, for fats of all kinds, and for protein concentrates now critically essential in poultry and animal feeds.

The evolution in utilization of sardines was accompanied by an evolution in fishing method. Lampara nets and small boats gave way to purse seines and boats comparable in size and far surpassing in catching ability the Pacific halibut schooners or North Atlantic trawlers. Where a night's catch of 10 to 20 tons had once been usual, loads of 100 to 200 tons are now commonplace. Correspondingly the annual take of sardines has grown from something less than 200 thousand tons to about 500 thousand tons.

During the past two decades, the low prices commanded by the products of the industry were a definite limiting influence on the intensity of fishing. The value of the sardine oil governed the industry's price structure and since oil must compete in a market dominated by lard, tallow, cottonseed oil and coconut oil, all normally produced in large volume, the prices of these fundamentally controlled the price of sardine oil and hence the intensity of fishing. Even under the wartime conditions with a substantial increase in the fats market, the price structure still offered the fishermen only 1-1/10 cents per pound for his catch.

The removal of price ceilings in 1946 was followed by a sharp increase in the prices paid to the fishermen. This rise, to 2 and 3 cents a pound, was much higher than the increase in general prices, a condition which was caused by the general scarcity of animal fats and proteins combined with an unusually poor catch. Whether, after the post war readjustment, the price of sardines will drop in relation to other commodities remains to be seen.

If, after the readjustment period, the price structure of the sardine industry reverts to its former relation to other prices, the catch of the individual fisherman will again have to be relatively high in order for him to make a living. This would tend to check the expansion of the fishery. If, however, the price of sardines remains high, it will be economically possible for the fishermen to operate at a lower level of abundance of sardines than would otherwise be possible. This would bring into question, in more acute form than ever before, the ability of the stock to replenish itself adequately to withstand the higher death rate caused by the more intense fishery.

During the decade ending in 1945 the fishery in California appeared to be stabilized at an annual catch of over 500,000 tons. In the 1945-46 season, however, the catch dropped to 400,000 tons and in 1946-47 it fell to 230,000 tons. It is known that this drop is partly due to poor reproduction in 1940 and subsequent years (following the very good reproduction of 1938 and 1939) resulting in a sharp decrease in the number of adult sardines in the sea. In addition the catch in central and northern California suffered because the sardines did not appear on the fishing grounds in the usual proportion as a result, perhaps, of unusual oceanic conditions.

Thus, the sardine fishery is at present reacting violently both to economic changes and to changes in the condition of the stock of fish in the sea. The final effects of economic changes depend to a large extent on the nature of the economic readjustment. The ultimate effects of biological changes can be interpreted only on the basis of information on conditions in the sea, information that has yet to be collected by means that have yet to be provided. The net outcome is problematical.

Among the world's sardines the Pacific sardine (Sardinops caerulea) is not the only species that supports an important commercial fishery. Sardina pilchardus in the Mediterranean and adjacent Atlantic waters, and Sardinops sagax in the western Pacific are intensively fished.